THALES

Building a future we can all trust

A value-driven, integrated approach to Model-Based Product Line Engineering

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Questions that arise when implementing Product Line Engineering practices in large organizations include:

What **methods** can be applied to architect, design and build the contents of a product line?

How to **align** the architecture and design of a product to market and business analyses?

How to **verify the consistency** of alternatives and options at different system levels?

How to guarantee that each defined configuration results in a **feasible and valid architecture**?

Is a **feature mode**l enough to understand what each product option or alternative consists of, or should tacit knowledge be made explicit to make informed design choices?

To tackle the challenges that arise when trying to implement PLE practices in large organizations, we require an

integrated Product Line approach

that connects and aligns market and business analysis, architecting, design, engineering and manufacturing,

anchored in Model-Based Engineering practices

enabling rigorous workflows and
facilitating a collaborative work between business domains

Today's content

Our building blocks:
Product Line Engineering & Model-Based Systems Engineering

The value-driven, integrated approach to
Model-Based Product Line Engineering, presented through a case study

Product Line Engineering (PLE)

Product Line

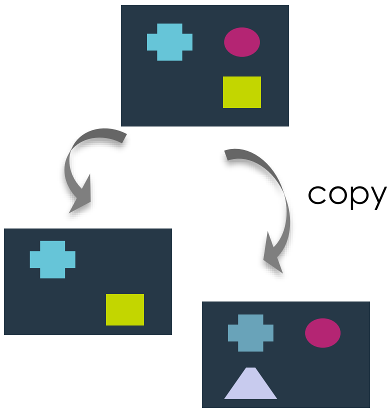
A family of similar products with variations in purpose, functions, and structure

PLE

The engineering of a product line, taking advantage of shared assets among the products and common production facilities

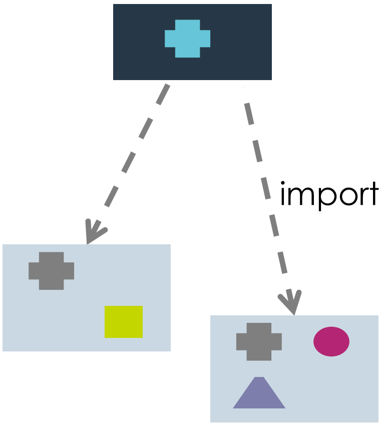
Principles of the product approach – Technical perspective

Clone and own



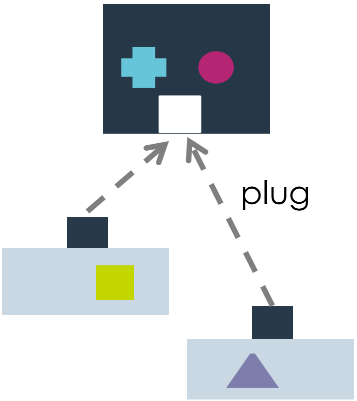
+ easy to use
+ independence
– no sharing
– Risk of Branching hell

Component library



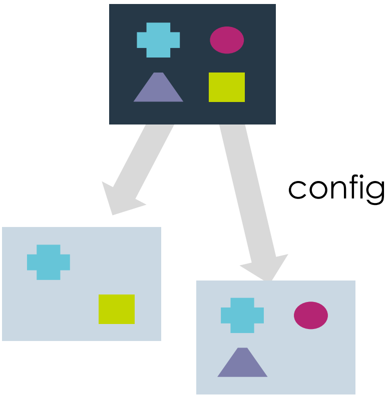
+ some sharing
+ simple interfaces
– small-scale reuse
– limited coverage
– some dependency

Framework



+ substantial reuse
+ standardization
– complex interfaces
– strong dependency

Superset platform (“150%”)



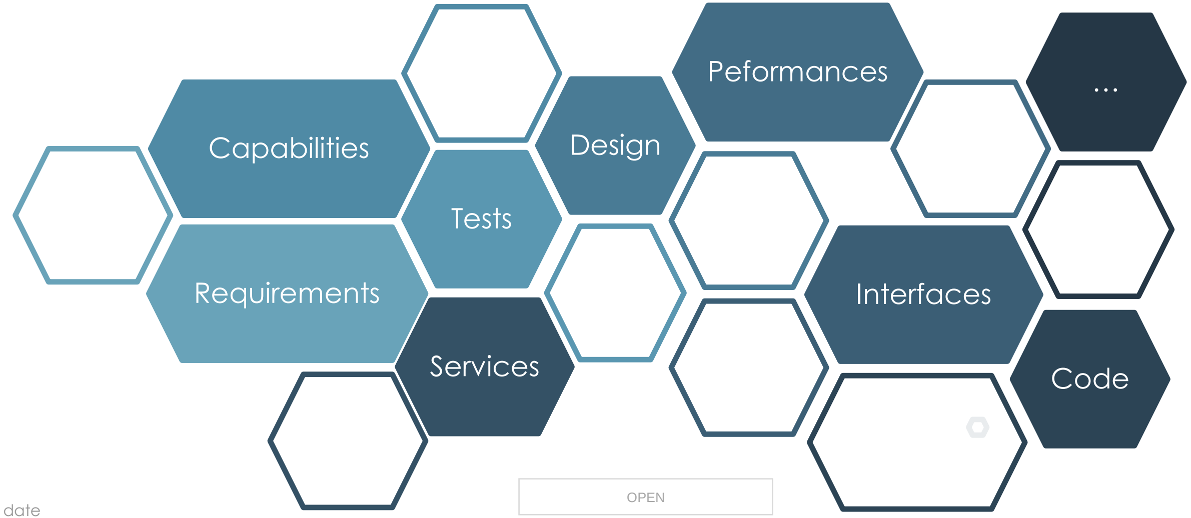
+ substantial reuse
+ automation
+ variability management
– complex configuration
– strong dependency

From K. Czarnecki, U. Waterloo

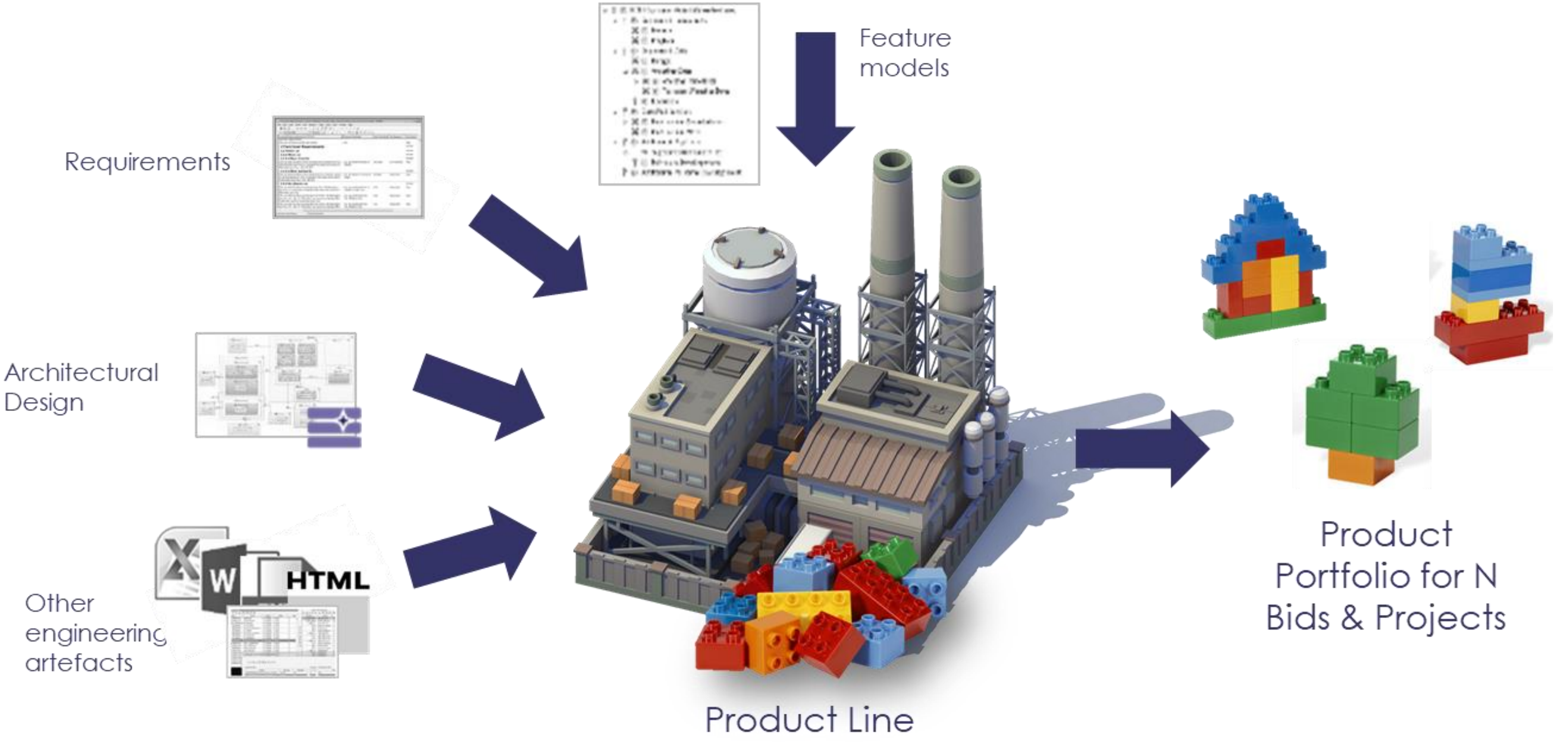
Features

A **feature** is a distinctive **characteristic** of a system of interest

- Allows to manage the commonalities (mandatory) or variability (option, alternative) of the product
- Covers both functional and non-functional aspects
- Can be understood by end-users and/or other stakeholders



Derivation process



Feature models

Requirements

Architectural Design

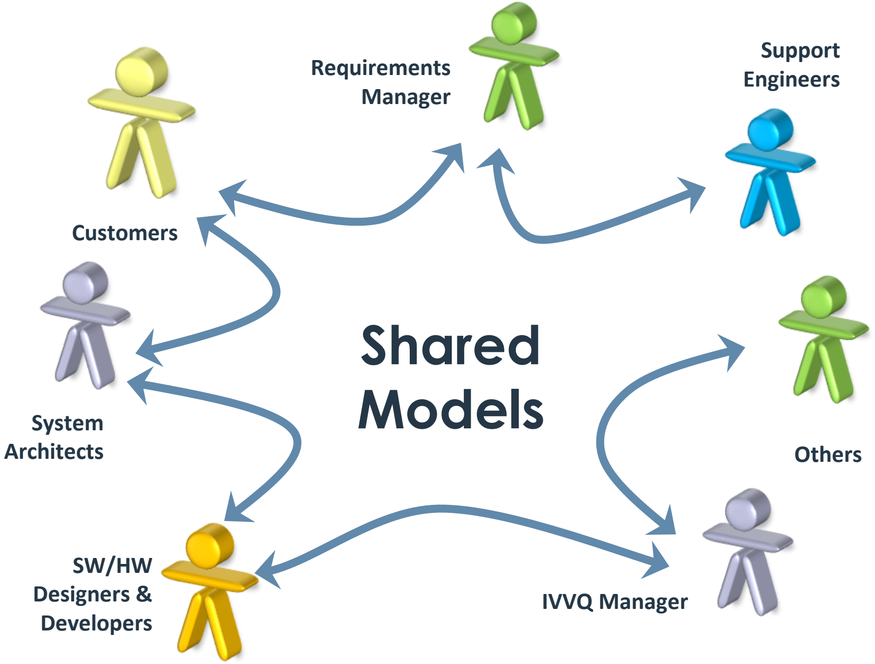
Other engineering artefacts

Product Line

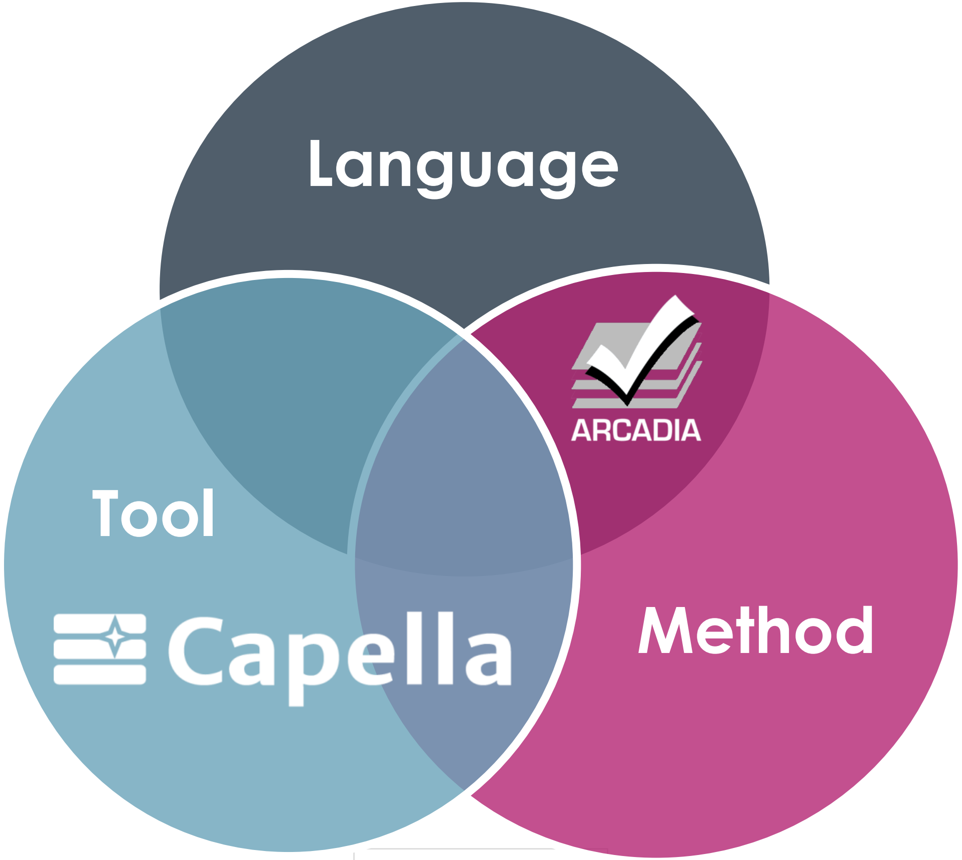
Product Portfolio for N Bids & Projects

Model-Based Systems Engineering (MBSE)

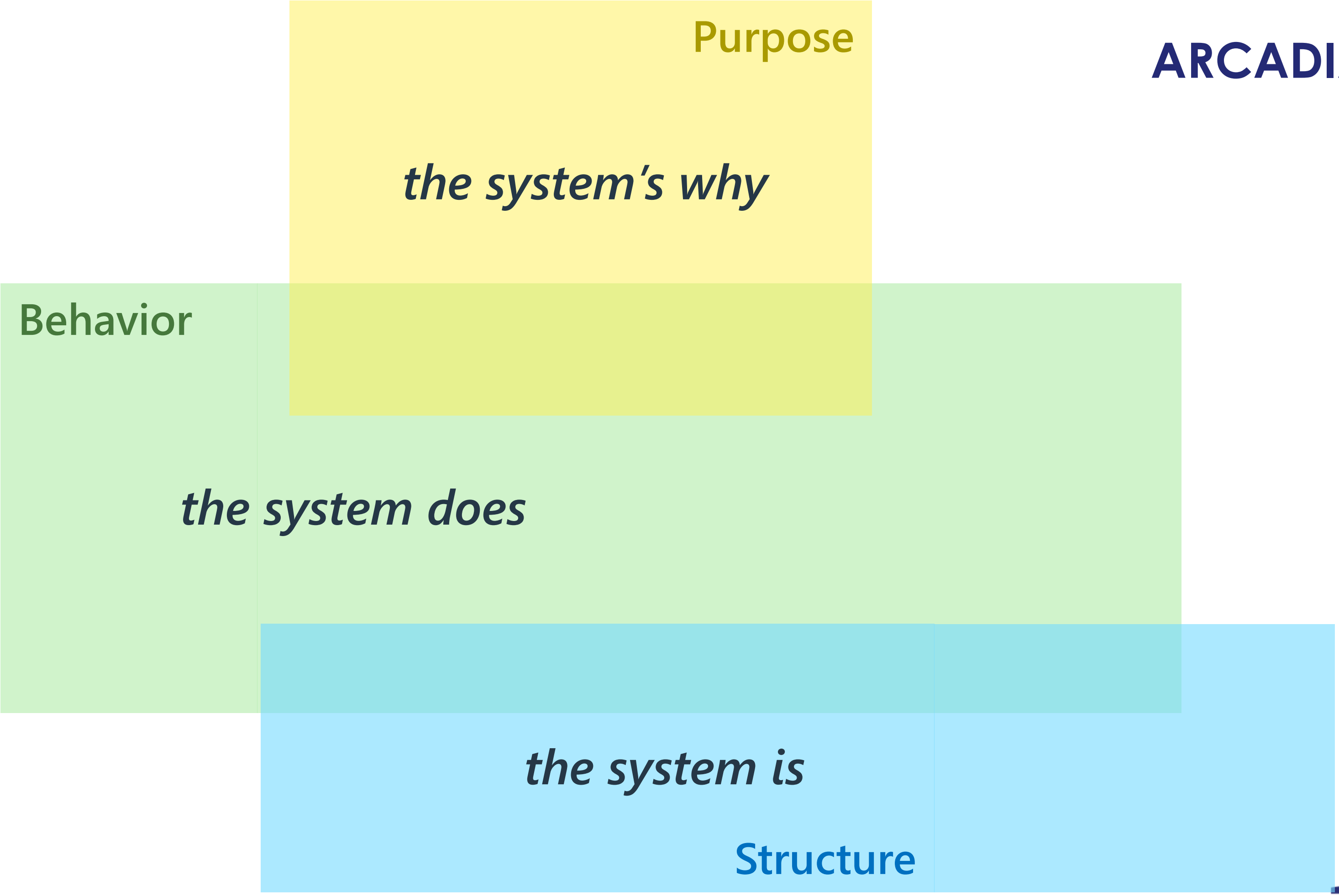
- Formalized application of **modelling techniques to support the engineering activities**, using a combination of static, dynamic and executable models
  - Focused on developing consistent architectures
  - Enabling analysis and supporting optimization, trade-off studies, and V&V
- A shift in the **nature of representation of systems**
  - From natural text and ad-hoc drawings to explicit, unambiguous, structured data and representations
- **Increased rigor**, improvements in quality and communication, traceability, productivity, etc.



The pillars of our MBSE approach



ARCADIA aspects



Purpose

the system's why

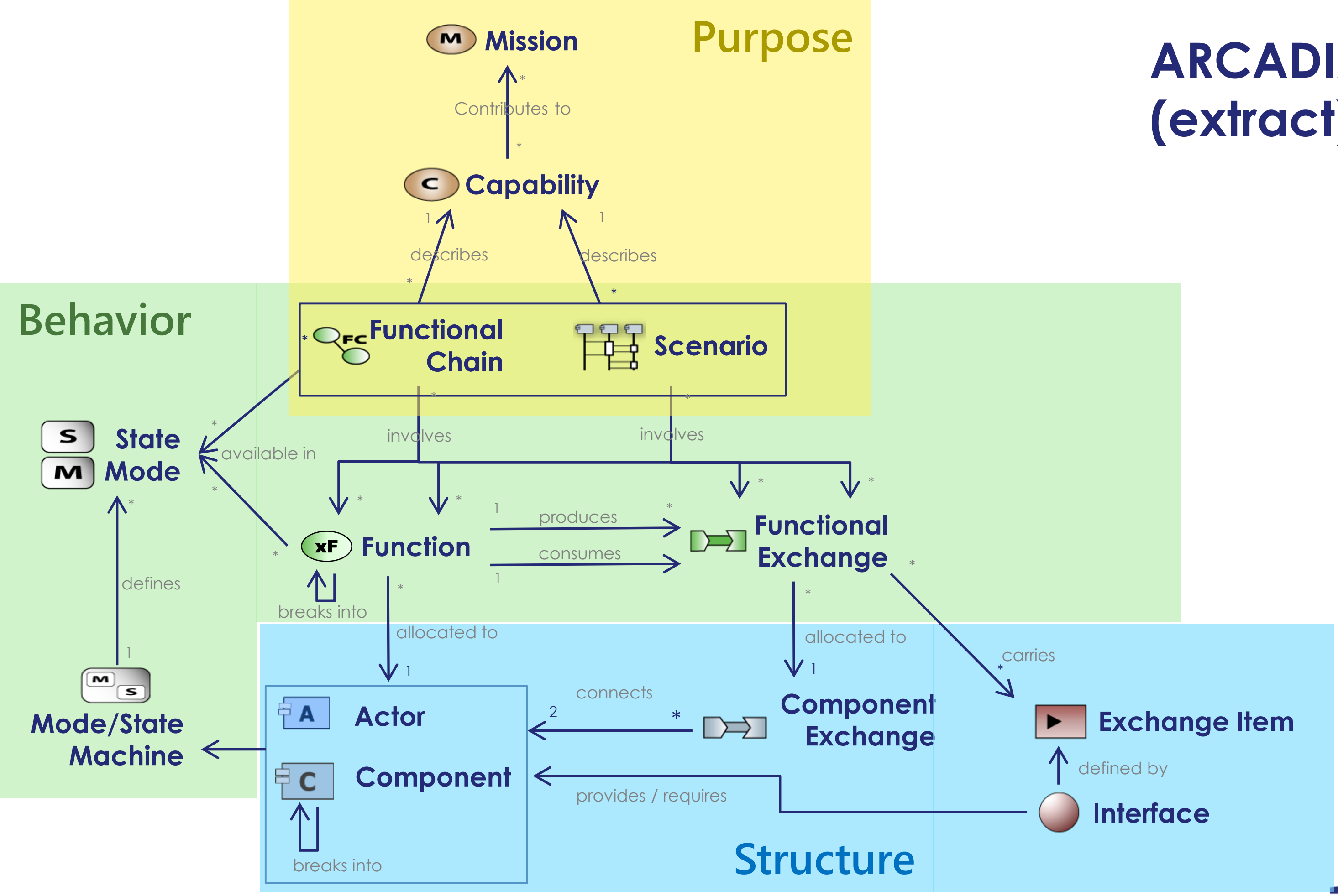
Behavior

the system does

the system is

Structure

ARCADIA vocabulary (extract)



ARCADIA Perspectives

ARCADIA

Arcadia drives you to adopt certain perspectives to ensure the consistency and completeness of your architecture design

	Perspective	Objective
NEED PERSPECTIVES	**Operational Analysis**	What the stakeholders need to accomplish
	System Needs Analysis	What the system has to accomplish for the stakeholders
SOLUTION PERSPECTIVES	**Conceptual Architecture**	How the system will work to fulfill expectations
	Finalized Architecture	How the system will be developed and built

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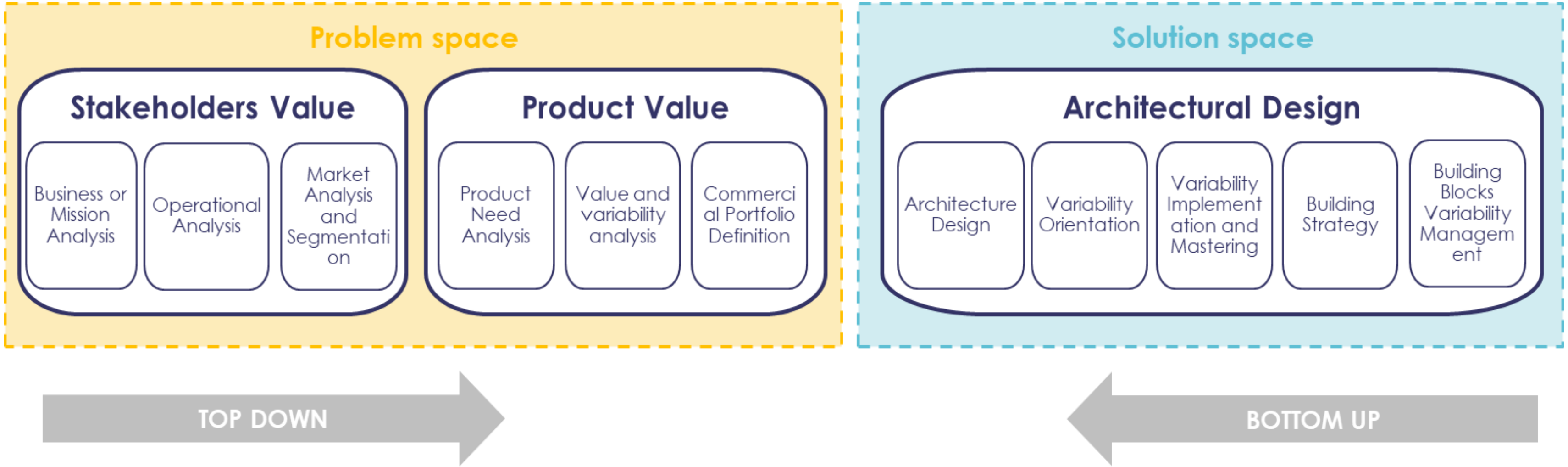
Value-driven, integrated approach to Model-Based Product Line Engineering


Problem space
Stakeholders Value
Business or Mission Analysis
Operational Analysis
Market Analysis and Segmentati on
Product Value
Product Need Analysis
Value and variability analysis
Commerci al Portfolio Definition
Solution space
Architectural Design
Architecture Design
Variability Orientation
Variability Implement ation and Mastering
Building Strategy
Building Blocks Variability Managem ent
TOP DOWN
BOTTOM UP

Stakeholders value perspective

3 threads of interrelated activities

Business and mission analysis

- Covers business strategy (business models, target markets and segmentation, product roadmaps, value propositions and differentiators), high-level operational needs and functionalities, architectural concepts or orientations

Operational analysis

- Formalizes the outputs coming from the business and mission analysis. The expectations of the stakeholders are expressed in terms of operational capabilities, missions, scenarios, operational processes and related operational activities

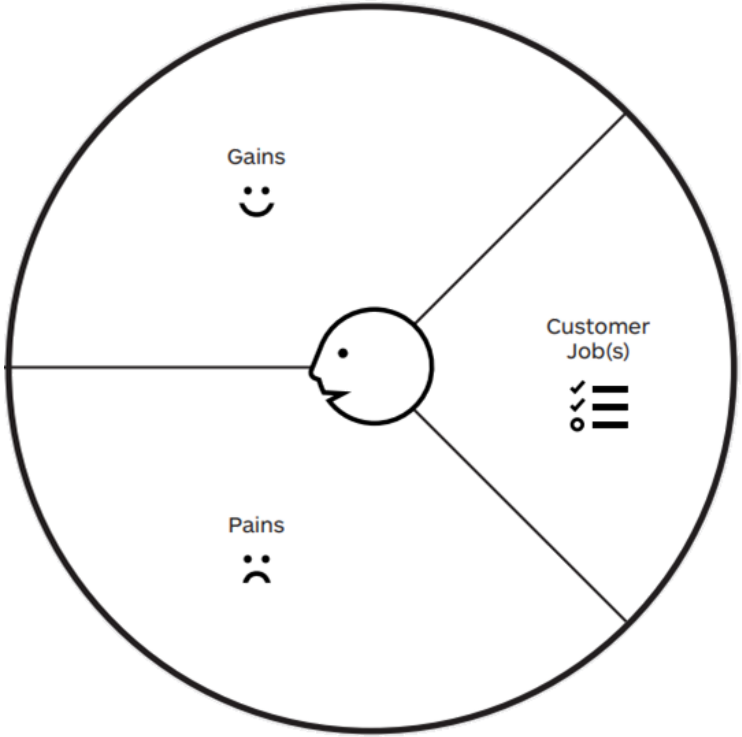
Market analysis and segmentation

- Customer profiles are established to describe each customer segment, collaboratively with marketing and sales teams. Throughout these analyses, stakeholder-level alternatives and options emerge.

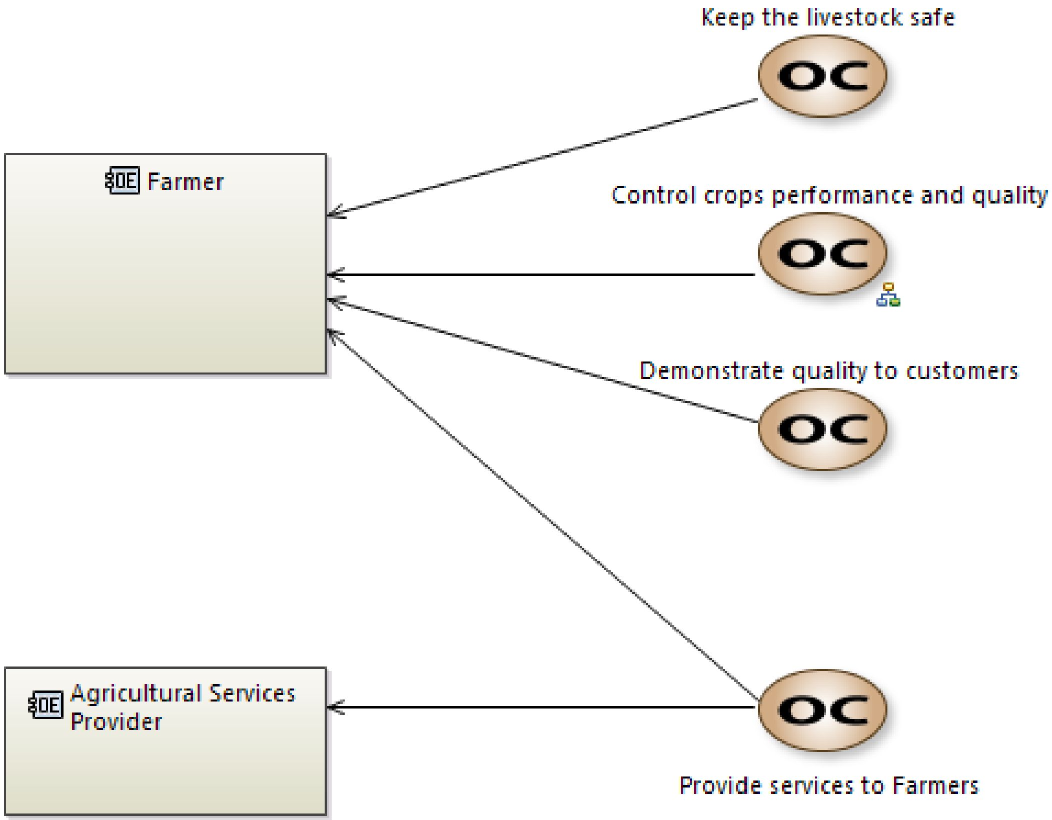
Value analysis – Customer profile

- The **customer profile** describes a specific customer segment in a structured and detailed way

- For each stakeholder,
  - **Jobs**: What the stakeholder is trying to get done in their work
  - **Pains**: Anything that annoys the stakeholder before, during and after trying to get a job done
  - **Gains**: The outcomes and benefits the stakeholder would welcome



Stakeholders operational capabilities


Keep the livestock safe
OC
Farmer
Control crops performance and quality
OC
Demonstrate quality to customers
OC
Agricultural Services Provider
OC
Provide services to Farmers

JOBS

OPEN

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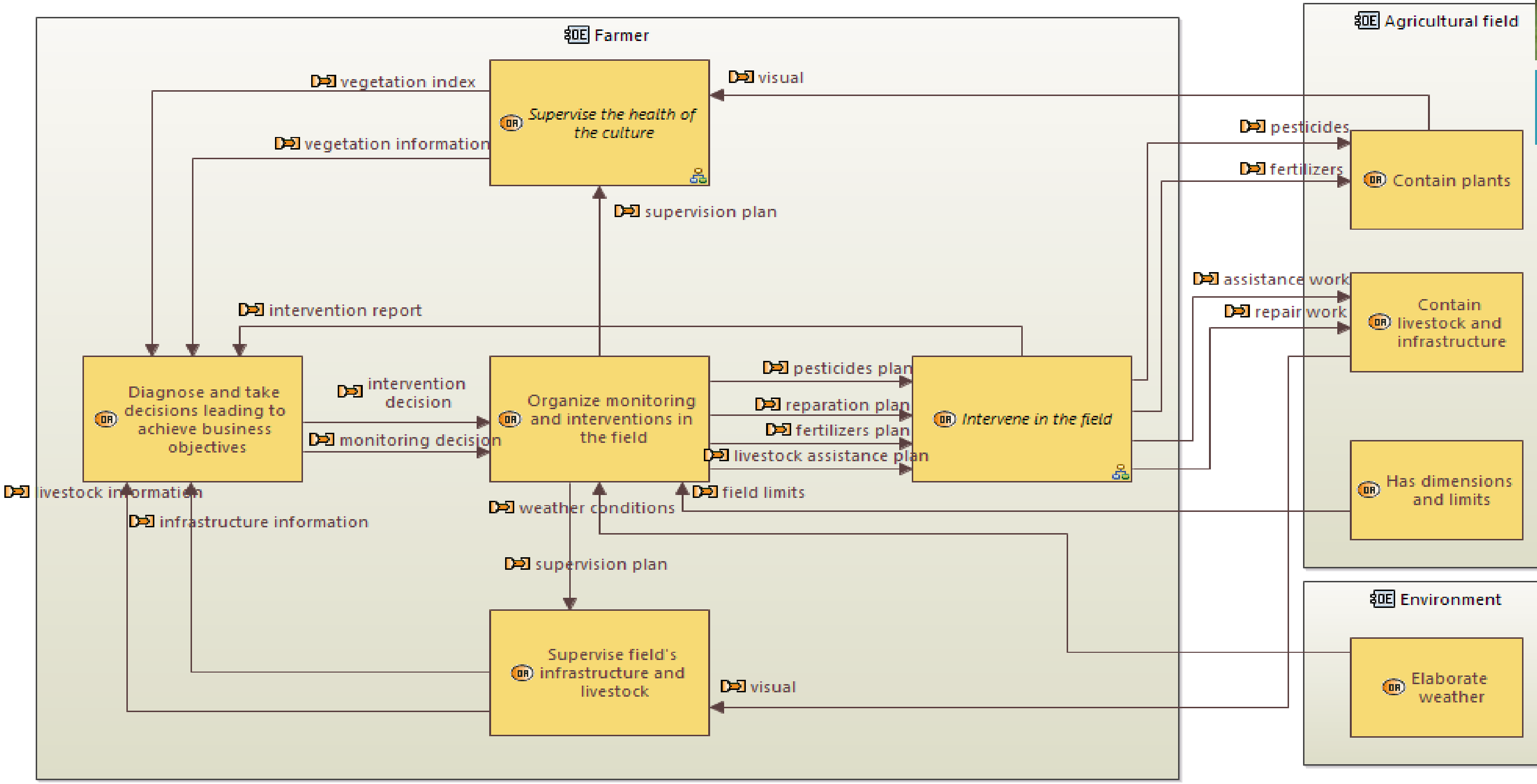
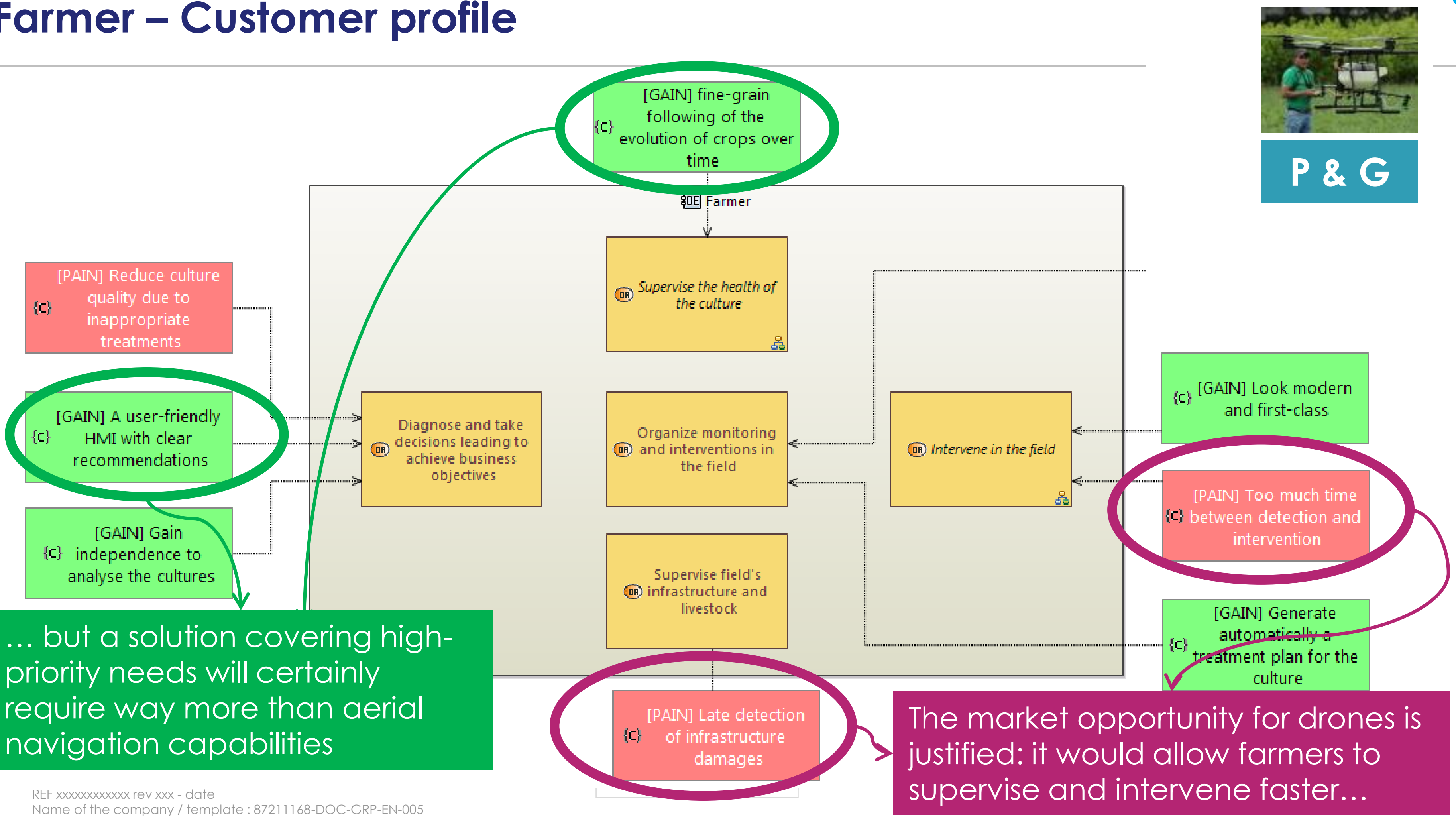
Operational activities



JOBS

Farmer – Customer profile


P & G
[GAIN] fine-grain following of the evolution of crops over time
{C}
Farmer
Supervise the health of the culture
[PAIN] Reduce culture quality due to inappropriate treatments
{C}
[GAIN] A user-friendly HMI with clear recommendations
{C}
[GAIN] Gain independence to analyse the cultures
{C}
Diagnose and take decisions leading to achieve business objectives
Organize monitoring and interventions in the field
Intervene in the field
Supervise field's infrastructure and livestock
[GAIN] Look modern and first-class
{C}
[PAIN] Too much time between detection and intervention
{C}
[GAIN] Generate automatically a treatment plan for the culture
{C}
[PAIN] Late detection of infrastructure damages
{C}

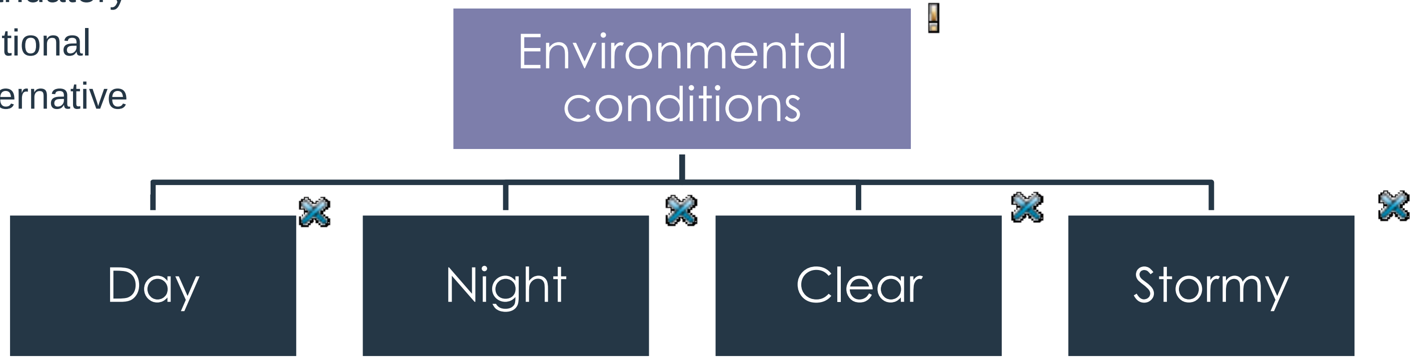
… but a solution covering high-priority needs will certainly require way more than aerial navigation capabilities

The market opportunity for drones is justified: it would allow farmers to supervise and intervene faster…

Variability emerging at operational analysis level

Variation Types:

- ! Mandatory
- ? Optional
- ⇔ Alternative
- ✖ Or



Key point – dimensioning variabilities can be captured even before defining the product of interest

Product value perspective

Product needs analysis

System needs analysis

- Establishes what the product shall accomplish for the stakeholders
- Performs functional and non-functional analysis
- Consolidates requirements

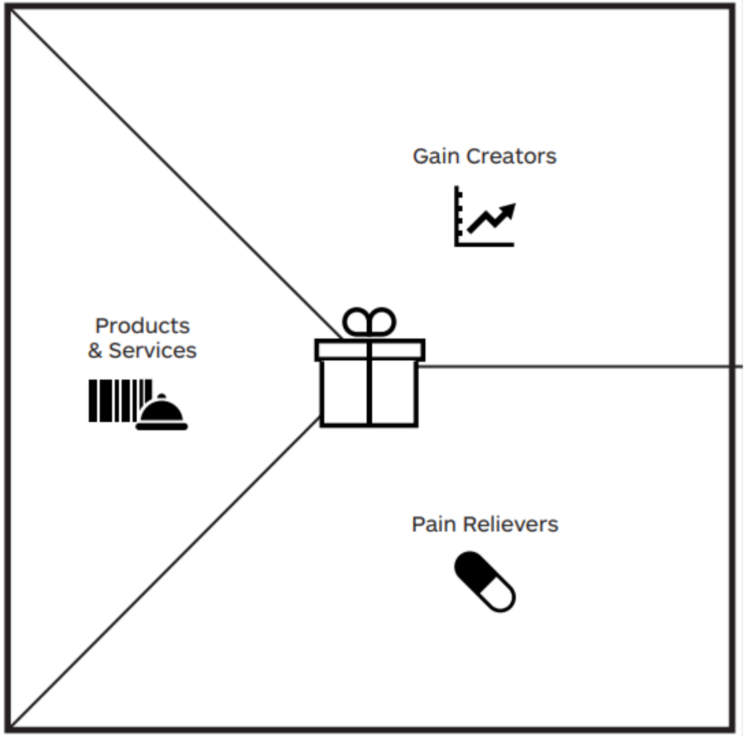
When performed at a Product level

- Is accompanied by a **product value** analysis
- Exhaustively covers all the needs of the targeted market segments (150% model)
- Starts identifying **commonalities and variabilities between market segments needs**

Product value analysis

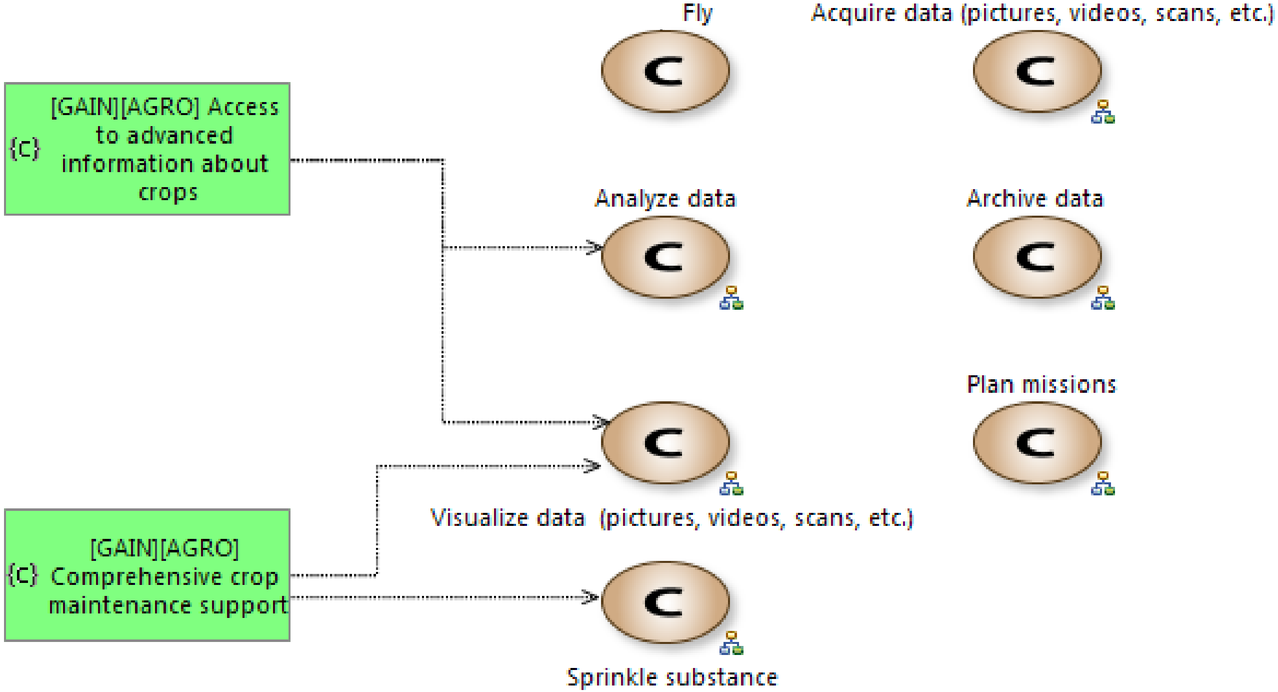
The **value map** describes the value proposition in a structured and detailed way

- **Products & Services**: what the product offers and what helps stakeholders complete their jobs
- **Gain creators**: how the products and services help create customer gains
- **Pain relievers**: how exactly the product and services help eliminate or reduce specific customer pains.



OPEN

Correlating value analysis and product capabilities



{C} [GAIN][AGRO] Access to advanced information about crops
{C} [GAIN][AGRO] Comprehensive crop maintenance support
Fly
Acquire data (pictures, videos, scans, etc.)
Analyze data
Archive data
Plan missions
Visualize data (pictures, videos, scans, etc.)
Sprinkle substance

Product needs variability analysis

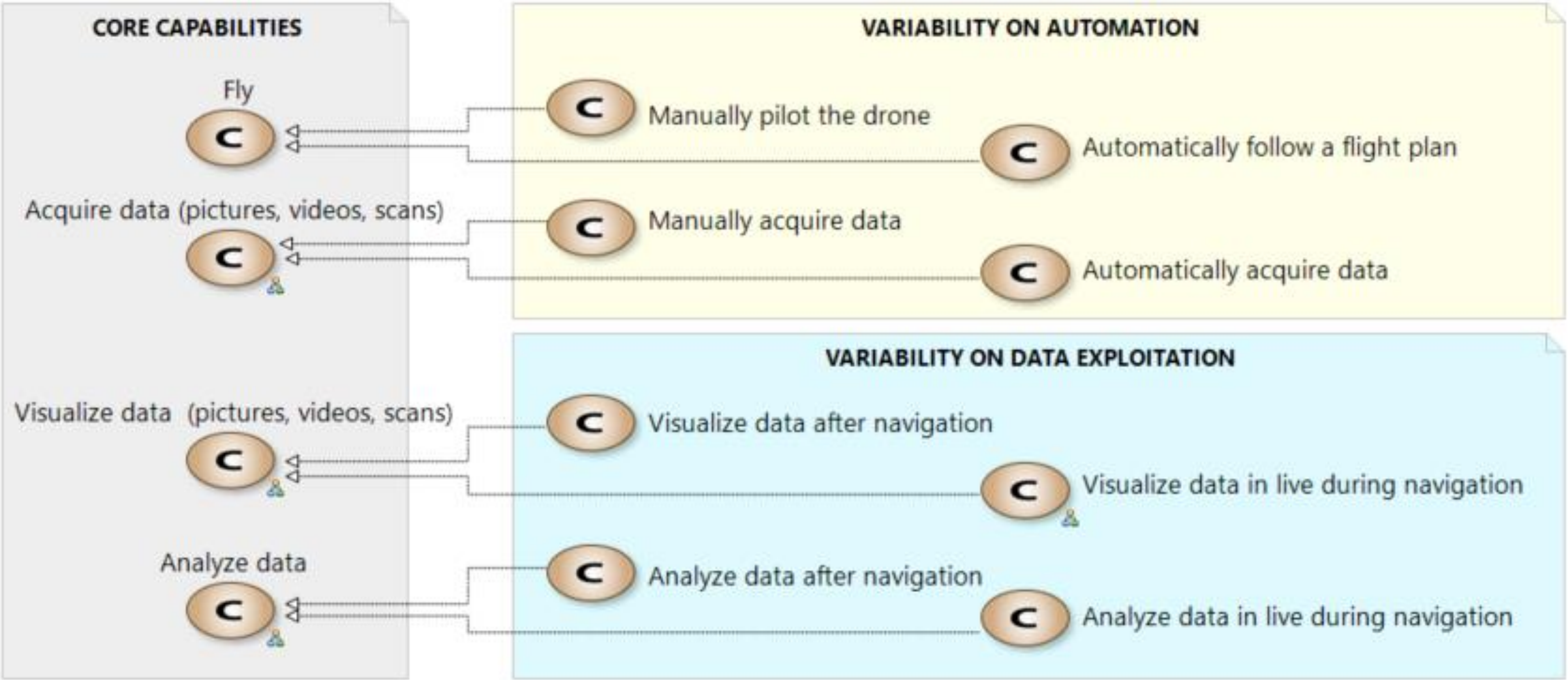
Possible sources of **variability** (not exhaustive)

- Variability already identified in operational analysis / stakeholder value analysis
- Market segments specificities, geographic specificities, etc.
- Non-functional concerns: e.g. safety controls due to regulatory frameworks
- Orchestration of features: e.g. switchover from auto to manual navigation mode

Commercial portfolio definition

- Definition of product standard configurations, which are selections of coherent features options or alternatives.

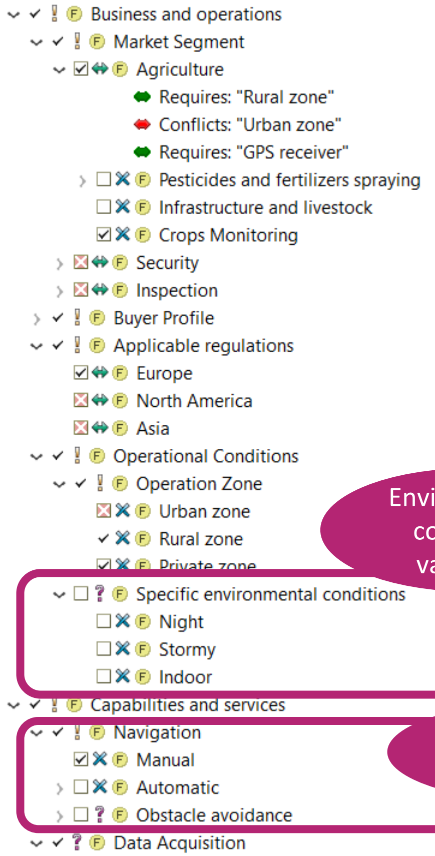
Variability on product capabilities


CORE CAPABILITIES
Fly
Acquire data (pictures, videos, scans)
Visualize data (pictures, videos, scans)
Analyze data
VARIABILITY ON AUTOMATION
Manually pilot the drone
Automatically follow a flight plan
Manually acquire data
Automatically acquire data
VARIABILITY ON DATA EXPLOITATION
Visualize data after navigation
Visualize data in live during navigation
Analyze data after navigation
Analyze data in live during navigation
C

Key point – Capabilities capture the most structuring variability, that will be reflected, enriched and formalized in the feature model

Need-level feature model and standard configurations

Agriculture LOW COST

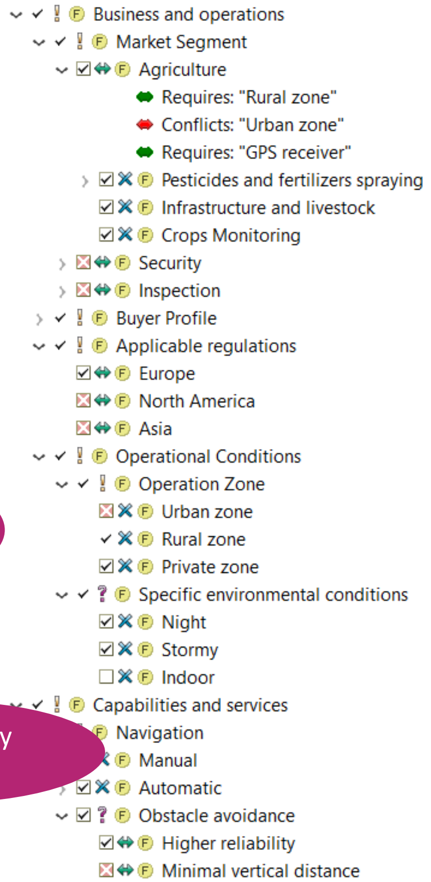


- ✓ ! Business and operations
  - ✓ ! Market Segment
    - ☑ Agriculture
      - Requires: "Rural zone"
      - Conflicts: "Urban zone"
      - Requires: "GPS receiver"
      - ☐ Pesticides and fertilizers spraying
      - ☐ Infrastructure and livestock
      - ☑ Crops Monitoring
    - ☒ Security
    - ☒ Inspection
  - ✓ ! Buyer Profile
  - ✓ ! Applicable regulations
    - ☑ Europe
    - ☒ North America
    - ☒ Asia
  - ✓ ! Operational Conditions
    - ✓ ! Operation Zone
      - ☒ Urban zone
      - ✓ Rural zone
      - ☑ Private zone
    - ☐ ? Specific environmental conditions
      - ☐ Night
      - ☐ Stormy
      - ☐ Indoor
- ✓ ! Capabilities and services
  - ✓ ! Navigation
    - ☑ Manual
    - ☐ Automatic
    - ☐ ? Obstacle avoidance
  - ✓ ? Data Acquisition

Environmental conditions variability

Fly Capability Variability

Agriculture HIGH END



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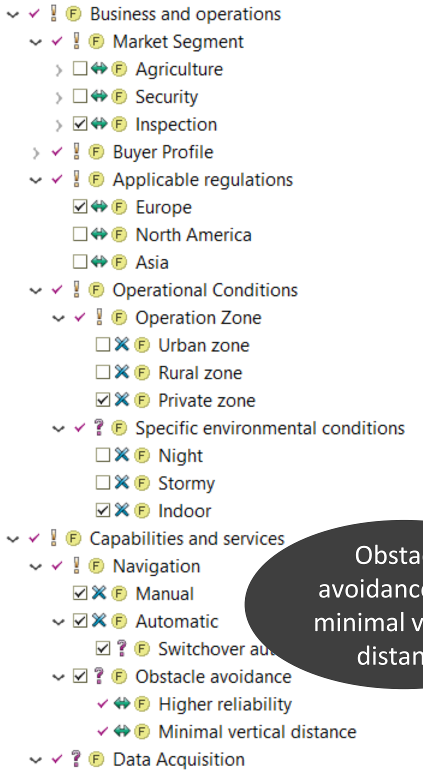
    - ✓ ! Operation Zone
      - ☒ Urban zone
      - ✓ Rural zone
      - ☑ Private zone
    - ✓ ? Specific environmental conditions
      - ☑ Night
      - ☑ Stormy
      - ☐ Indoor
- ✓ ! Capabilities and services
  - Navigation
    - Manual
    - ☑ Automatic
    - ☑ ? Obstacle avoidance
      - ☑ Higher reliability
      - ☒ Minimal vertical distance

Aircraft Inspection



- ✓ ! Business and operations
  - ✓ ! Market Segment
    - ☐ Agriculture
    - ☐ Security
    - ☑ Inspection
  - ✓ ! Buyer Profile
  - ✓ ! Applicable regulations
    - ☑ Europe
    - ☐ North America
    - ☐ Asia
  - ✓ ! Operational Conditions
    - ✓ ! Operation Zone
      - ☐ Urban zone
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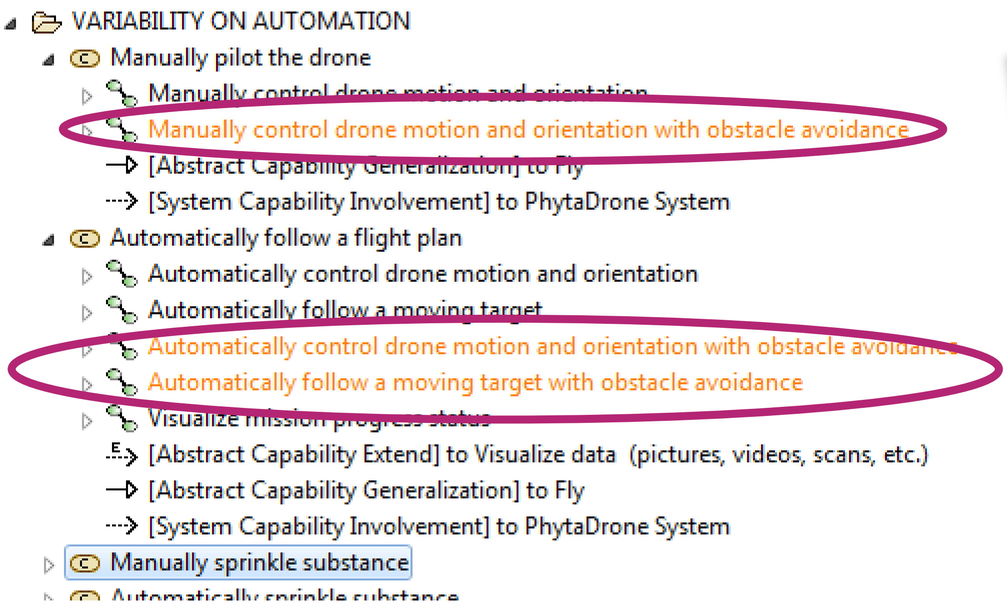
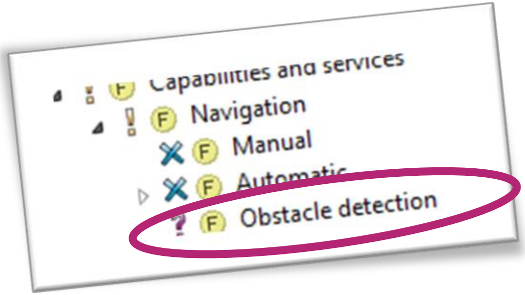
      - ☑ Private zone
    - ✓ ? Specific environmental conditions
      - ☐ Night
      - ☐ Stormy
      - ☑ Indoor
- ✓ ! Capabilities and services
  - ✓ ! Navigation
    - ☑ Manual
    - ☑ Automatic
      - ☑ ? Switchover au
    - ☑ ? Obstacle avoidance
      - ✓ Higher reliability
      - ✓ Minimal vertical distance
  - ✓ ? Data Acquisition

Obstacle avoidance with minimal vertical distance

Variability on functional chains



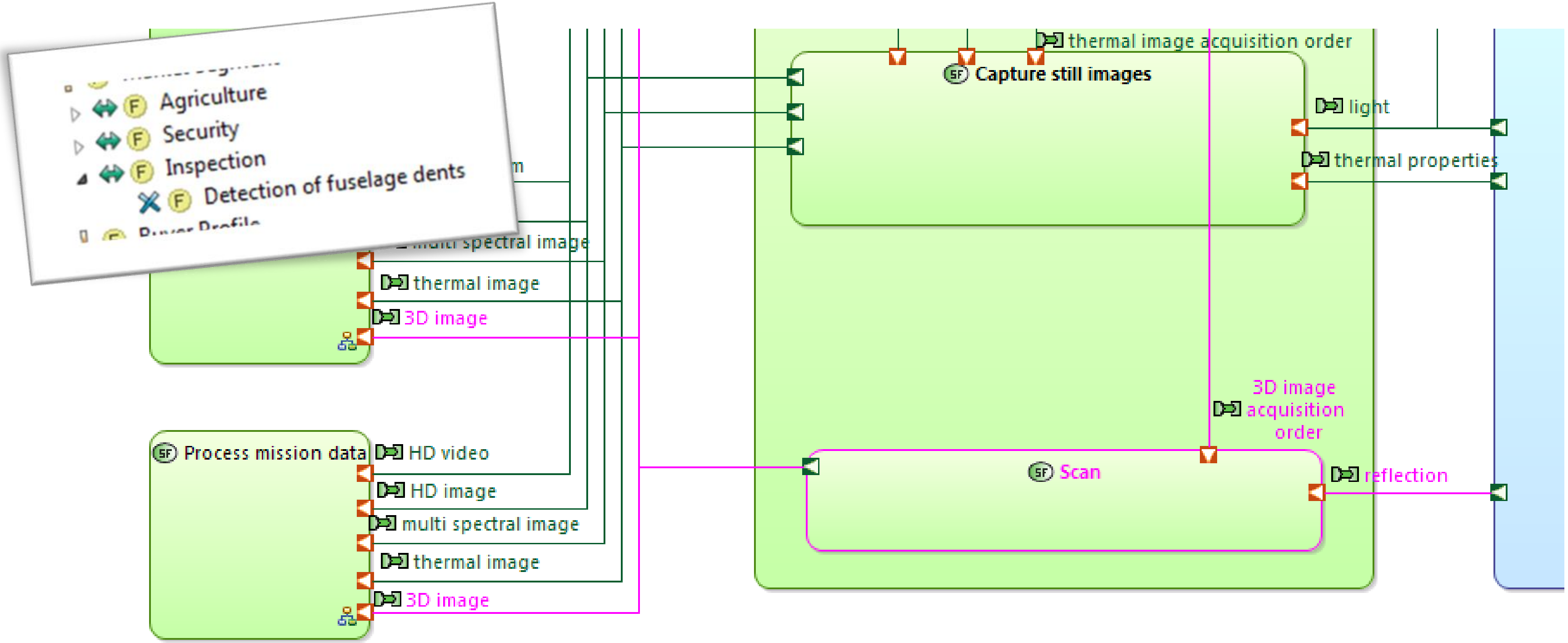
- VARIABILITY ON AUTOMATION
  - Manually pilot the drone
    - Manually control drone motion and orientation
    - Manually control drone motion and orientation with obstacle avoidance
    - [Abstract Capability Generalization] to Fly
    - [System Capability Involvement] to PhytaDrone System
  - Automatically follow a flight plan
    - Automatically control drone motion and orientation
    - Automatically follow a moving target
    - Automatically control drone motion and orientation with obstacle avoidance
    - Automatically follow a moving target with obstacle avoidance
    - Visualize mission progress status
    - [Abstract Capability Extend] to Visualize data (pictures, videos, scans, etc.)
    - [Abstract Capability Generalization] to Fly
    - [System Capability Involvement] to PhytaDrone System
  - Manually sprinkle substance
  - Automatically sprinkle substance



- Capabilities and services
  - Navigation
    - Manual
    - Automatic
    - Obstacle detection

Key point – simultaneous construction of Architecture and Feature Models

Variability on functions



Key point – fine-grained variabilities can be carried by Functions, Functional Exchanges, …

Product architectural design perspective

Product architecture

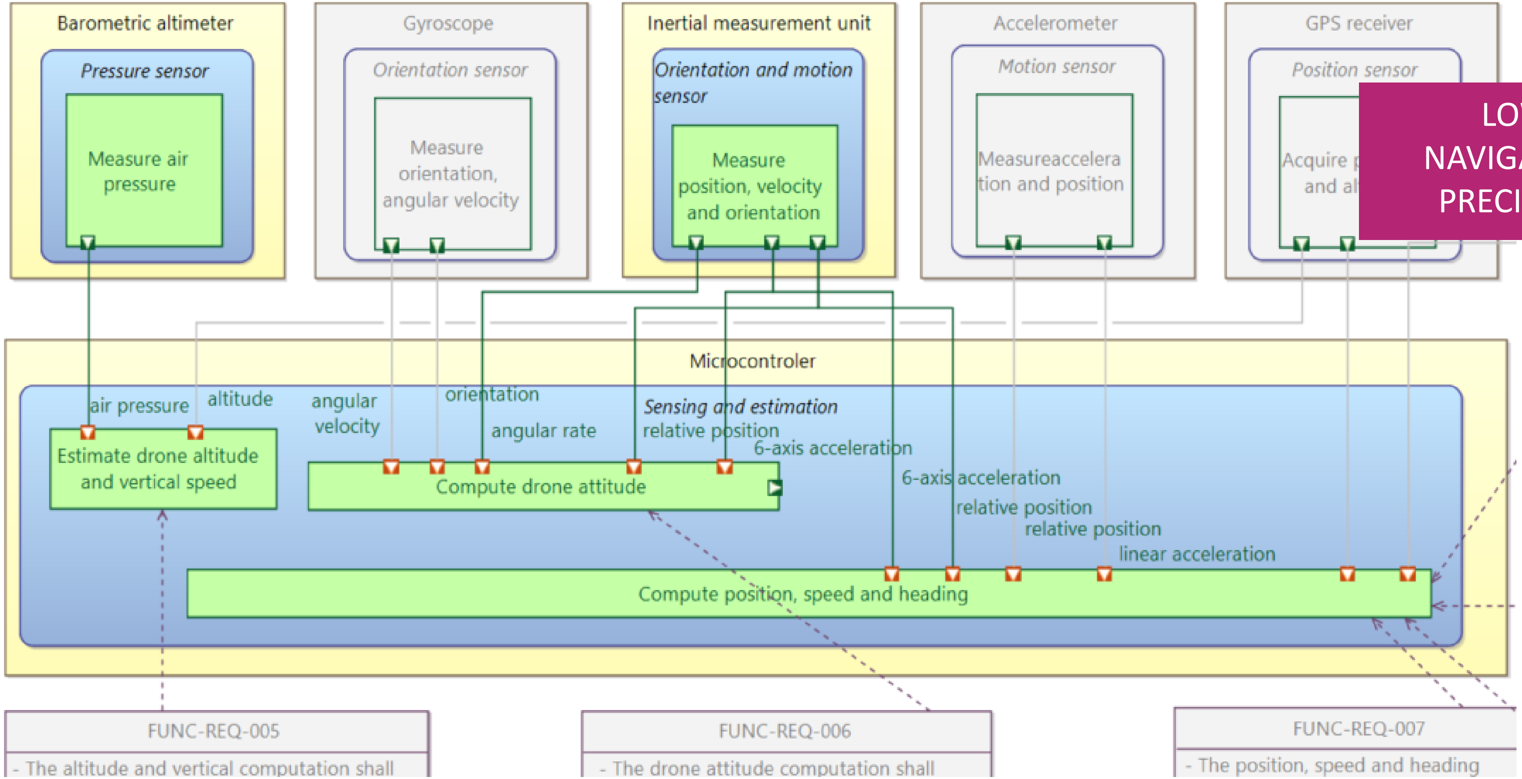
Architecture modeling

- Perform solution functional analysis and non-functional analysis
- Define the components: scope (functional expectations) and interfaces (between them and with external actors)
- Conduct co-engineering (e.g. performance, safety, cyber, …)

At a product level

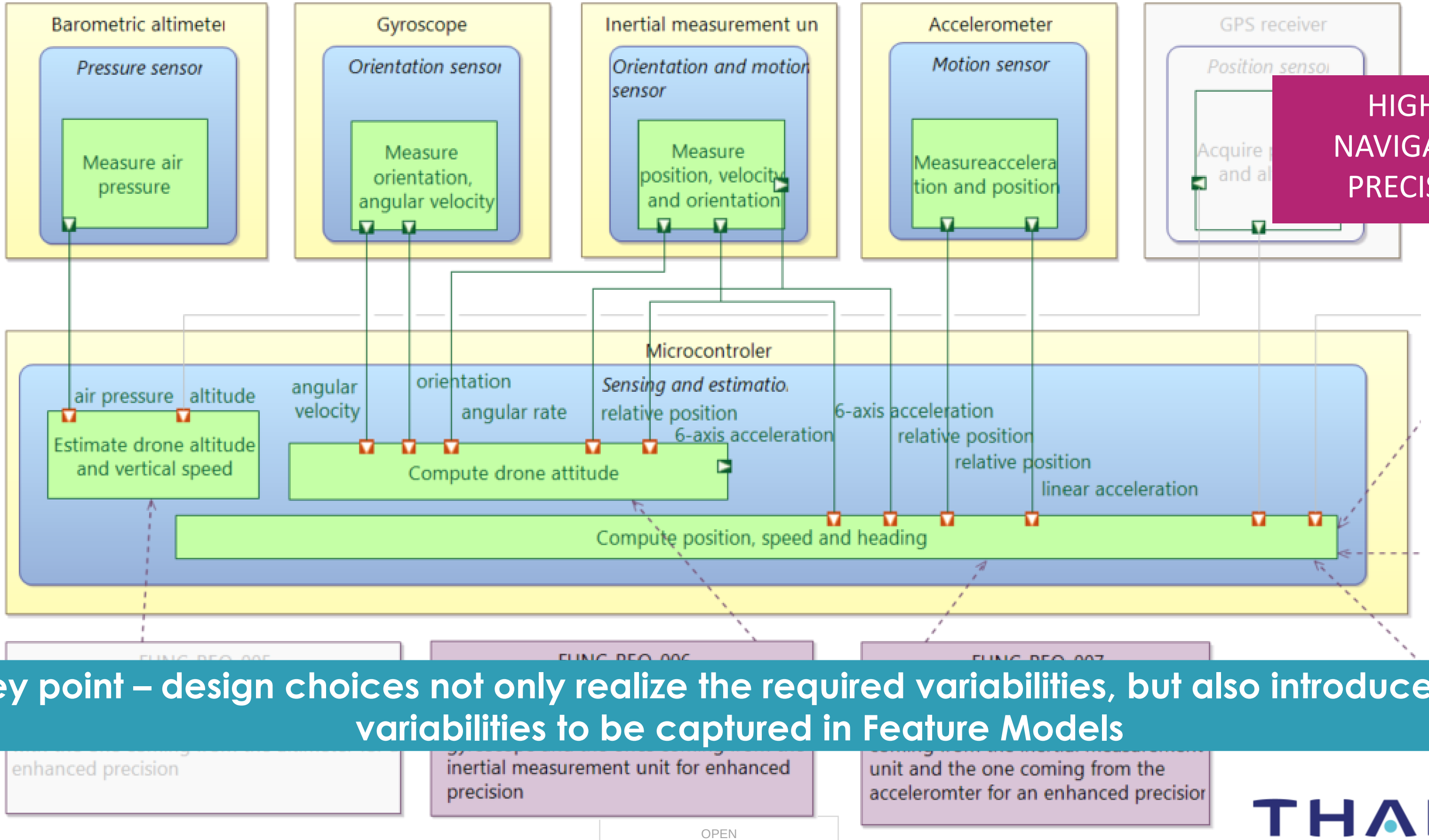
- Design a solution that satisfies the needs of the addressed market segments: the **« 150% » product architecture**
- **Master impacts of variability**, check the consistency between architecture, feature model and configurations contents
- Easily produce / **initialize project-specific solutions**

Product architecture



LOW NAVIGATION PRECISION

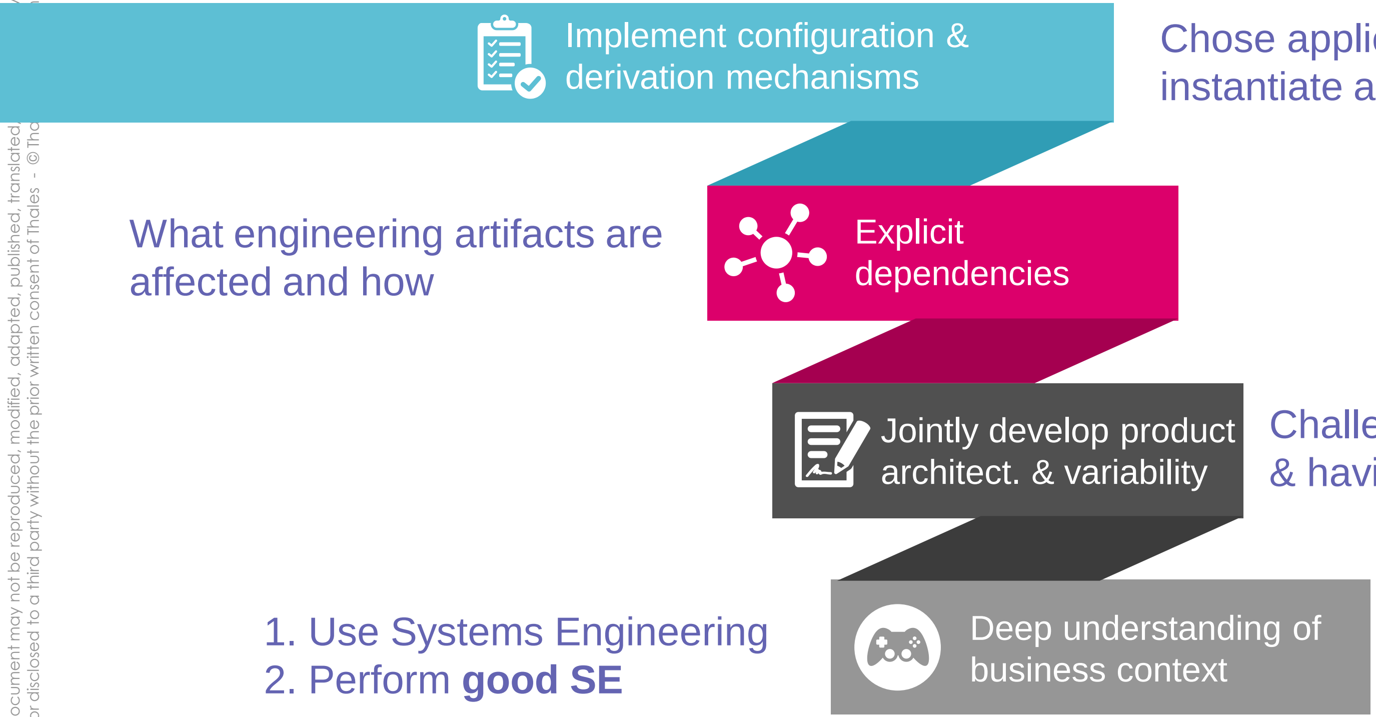
Product architecture



HIGHER NAVIGATION PRECISION

Key point – design choices not only realize the required variabilities, but also introduce new variabilities to be captured in Feature Models

Key messages



Implement configuration & derivation mechanisms

Chose applicable variants and instantiate asset repositories

Explicit dependencies

What engineering artifacts are affected and how

Jointly develop product architect. & variability

Challenges: defining **core** assets & having one single point of truth

Deep understanding of business context

1. Use Systems Engineering
2. Perform **good SE**

A value-driven approach founded on Model-Based Engineering, is a key enabler for effectively implementing Product Line Engineering practices in large organizations

Thank you